INVESTIGATION ON MECHANICAL AND MODAL PROPERTIES OF ALUMINIUM BASED FIBRE METAL LAMINATES

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I chain-like declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Kombinasi bahan antara aloi dan bahan komposit telah lama digunakan sebelum mencapai tahap prestasi yang diperlukan ketika ini. Untuk mencapai kombinasi sifat-sifat bahan dan prestasi yang terbaik, adalah penting untuk mengkaji tingkah laku dinamiknya. Selain itu, bagi mengelak timbulnya masalah yang berkait dengan getaran, adalah penting untuk mendapatkan frekuansi tabii dan bentuk ragam semasa pemilihan bahan. Projek ilmiah ini dijalankan untuk mengkaji sifat mekanik aluminium aloi dan bahan komposit. Projek ini juga menilai tingkah laku dinamik kombinasi antara aluminium aloi (Al-2024-T0) dan tiga bahan komposit yang berbeza (CFRP, GFRP, UD-CFP) dengan menggunaka ujian getaran bebas. Plat fiber metal laminates (FML) yang digunakan sebagai specimen dibuat dengan menggunakan kaedah pengacuan mampatan. Manakala, kaedah fabrikasi mengikut piawaian ASTM D3039 dan sifat mekanik plat digunakan untuk kaedah ujian tegangan. Penilaian frekuansi tabii dan bentuk ragam FML dengan aluminium aloi (Al-2024-T0) dan tiga bahan komposit yang berbeza, dinilai melalui konfigurasi yang berbeza susunan iaitu 2/1 dan 3/2, dalam pelbagai jenis keadaan sempadan., Ujian ragaman menggunakan hentaman tukul dengan pergerakan sensor yang berubah dilaksanakan berdasarkan piawaian E756. Pada masa yang sama, model kaedah unsur terhingga yang menggunakan perisian komersial ABAQUS juga digunakan untuk menentukan frekuansi tabii dan bentuk ragam. Keputusan daridada eksperimen ragaman telah dibandingkan dengan keputusan simulasi unsur terhingga (FEA). Keputusan menunjukkan frekuansi tabii plat FML meningkat apabila banyak lapisan Al terbenam dalam lapisan komposit. Ia menunjukkan peningkatan peratusan frekuansi tabii dari 29.41 % sehingga 71.89 %. Keputusan kajian juga menunjukkan, frekuansi tabii pada plat FML bergantung pada keadaan sempadan dengan peratusan peningkatan 54.36 % hingga 88.53 %. Bentuk ragam telah diplotkan untuk plat berlapis yang berlainan dengan bantuan ABAQUS and ME'scopeVES dalam mendapatkan ketepatan bentuk ragam. Keputusan kajian ini disahkan dengan hasil dapatan untuk ralat antara analisis berangka (simulasi) dan eskperimen ujian ragaman adalah 0.08% sehingga 16.17%. Kesimpulannya, dengan kehadiran plat aluminium aloi dalam lapisan komposit, nilai frekuansi tabii akan meningkat. Keadaan sempadan sangat mempengaruhi nilai frekuansi tabii kerana kesan halangan di tepi.

ABSTRACT

The combination of materials between metal alloys and composite materials has been used for thousands of years to reach better performance requirement. To achieve the best combination of material properties and service performance, a study on the dynamic behaviour is one of the main points to be considered. Besides, it is important to investigate the natural frequency and the possible mode shape of the selected of the materials to avoid problems related to vibrations. This master project was aimed to investigate the mechanical properties of aluminium alloys and composite materials. At the same time, the dynamic behaviour of combination between aluminium alloys (Al 2024-T0) and three different composite materials (CFRP, GFRP, UD-CFP) by free vibration test also evaluated. Compression moulding technique was used to fabricate the fibre metal laminate (FML) plates. The fabrication method was according to ASTM D3039 standard and mechanical properties of the plate were determined from the tensile test method. Variation of natural frequency and mode shape of FML based on the aluminium alloys (Al 2024-T0) and three different composite materials were evaluated through different configuration lay-up of 2/1 and 3/2 stacking sequences with multiple boundary conditions. Based on E756 standard, modal testing using impact hammer with roving accelerometer method was carried on to the specimens. Finite element analysis (FEA) models by using commercial ABAQUS software was used to determine natural frequency and mode shape. The experimental results from modal testing were then compared with the FEA values. It was found that, the natural frequency of the FMLs plates increased when more Al layers were embedded in the composite layers. The results reveal that a percentage increase in natural frequency from 29.41 % to 71.98 %. Meanwhile, the percentage increment in natural frequency was from 54.36 % to 88.53 % between fixed-free and fixed-fixed boundary conditions. The vibration analysis of FML plates were validated, where the percentage error between numerical analysis and experimental results are observed to be 0.08 % to 16.17 %. In conclusion, with the presence of aluminium alloy plates in the composite layers, the natural frequency will increase as the value of stiffness increase. The boundary conditions significantly affected the natural frequency of FML plates because of the restraint effect at the edges.

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LIST OF ABBREVIATIONS

FMLs	Fibre metal laminates
Al	Aluminium
GFRP	Glass fibre reinforced polymer
CFRP	Carbon fibre reinforced polymer
UD-CFP	Unidirectional carbon fibre prepreg
EMA	Experimental modal analysis
FEA	Finite element analysis
DOF	Degree of freedom
FRF	Frequency response function
ARALL	Aramid reinforced aluminium laminates
GF	Glass fibre
GE	Glass epoxy
CF	Carbon fibre
CE	Carbon epoxy
SRPP	Self-reinforced polypropylene
GLARE	Glass fibre reinforced aluminium laminates
L/R	Length/Radius
L/H	Length/Height
UD	Uni-Directional
^{o}F	Fahrenheit
E	Modulus Elasticity
S4R	4-node, quadrilateral, stress/displacement shell element
C3D8R	Eight-node brick element with reduced integration
3D	Three-dimensional
MCST	Modified couple stress theory
a/b	Width/Length
NI	National Instrument
ARALL	Aramid fibre reinforcement aluminium laminates
CARALL	Carbon fibre reinforcement aluminium laminates

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